Prioritized Technology: Low Temperature Actuators and Mechanisms – Bearings

Technical Goal

1. Cryogenic bearings used in actuators and mechanisms that can survive -240˚K to 125˚K temperature cycling and operate at -240˚C
   a. Gas bearing (Gas is functionally a lubricant)
   b. Liquid bearing (cryogenic fluid is functionally a lubricant)
   c. Magnetic bearing (no lubrication). These need to be stiffer, less bulky, less massive
   d. Non-lubricated (self-lubricating) bearings. These need better service life and preferably generate no wear debris
   e. Dry film lubricated bearing

Technical Status

Many of the current technology can survive -190C, but for very short time or few cycles.

- Gas bearings (for high RPM applications): e.g in Hubble, but need even lower temperature. DoD uses them a lot.
- Liquid bearing: in-situ liquid (e.g. liquid methane for lakes)
- Active Magnetic bearings: TRL 4: limited for cryo applications due to mass, volume, power (electronics), low stiffness
- Permanent magnetic bearing exist. (Military investments). TRL 1
- Non-lubricated bearing:
  - TRL3: Bulk Metallic Glass BMG
  - TRL2: GRC Nitinol-60 (bearing material) -
  - Hybrid ceramic: steel races with Silicon Nitride
- Need to check cost for testing facility for cryo liquid bearing. Difficult…. TRL-0

Mission Applications

1. Europa [Near Term] robotic arm, gimballed antenna and camera requires a range of capabilities (lubrication, bearings, actuators and gearboxes).
2. Titan landers [Mid/Far term] pin point landing enabled. If capability realized, mission duration will be extended
3. Ice penetration and sampling on Ocean Worlds in the Mid/Far Term on missions would be extended from a couple weeks to few months.
4. Enabling this low temperature technology will allow us to reduce mass, power consumption (no heaters), and thermal losses (less cables) which ultimately, extends mission life. If actuators need not need heaters to operate, more power would be available for instrument operation and would extend the mission life. e.g. M2020, it could take up to 3 hours with energy as high as ~400Wh in order to warm up one of the arm actuators from -100C to -30C. Having actuators that operate at -240 would save energy and warm up time, which would increase science operating time and extend mission life. Thermal leaks will be reduced with no heater, PRT and control cables. The heat loss for a 1 meter 20AWG copper that links cold sink at -240˚C to hot source at 10KC is ~0.2W. Reducing the number of wire from 20 wires to 10, would save about 2W power. Fewer heaters also help reduce thermal contamination of the area of interest. Although heaters, PRTs, and thermostat are low mass, savings from no MLI could be considerable as the typical A142 20-layer MLI is 1kg/m2. Required MLI is highly dependent mission architecture but baseline area for MSL type mission is about 3-4 m2.
5. Another improvement very much needed is to increase target lifetime low temp cycles of operation from 500-1000 cycles to a few million cycles for the actuators. For Mars2020, the requirement for MOXIE is to run 3000rpm for 10 hours; translating to about 4 million cycles testing needed (2X life). In addition, percussion actuators requirement is 25Hz for 30 hours (or 5.4 million cycles if tested at 2X life).
6. Enabling these lower temperature technologies will enable science in Europa, Titan, and other ocean worlds.